PAMELA lattice and magnets
- Deriving the parameters needed for Zgoubi

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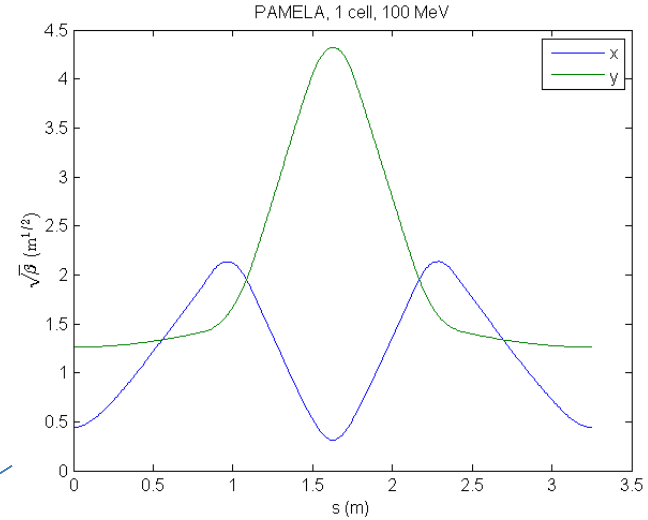
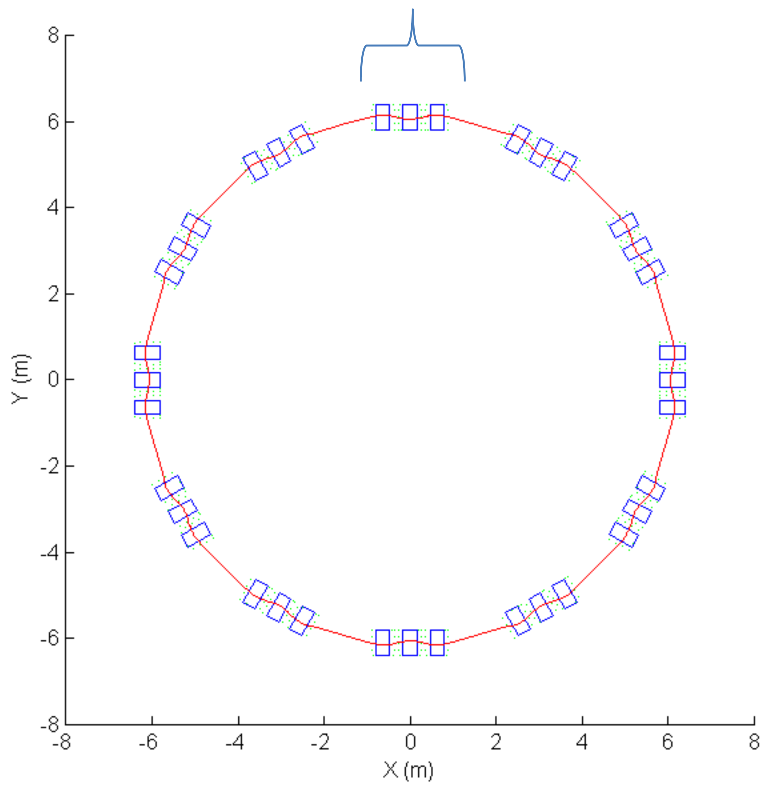
PAMELA

Closed orbit and Twiss parameters for a 100 MeV proton, computed using a Matlab script based on equations from the Zgoubi manual.

These must be obtained using Zgoubi first, before moving on to dynamic aperture calculation.





Lattice parameters

Obtained from PAMELA papers.

1 cell

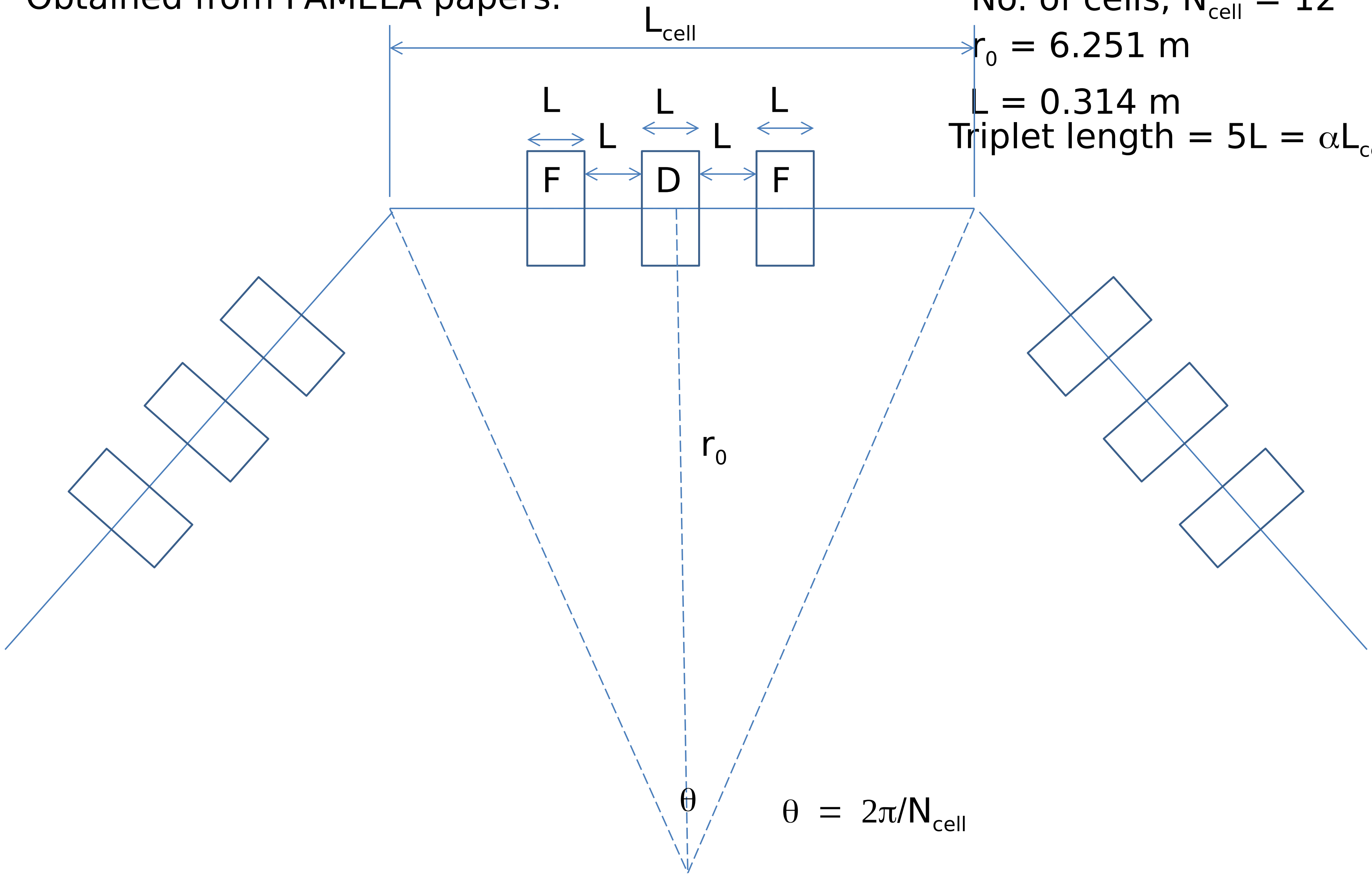
Packing factor, α = 0.48

No. of cells, N_{cell} = 12

r_0 = 6.251 m

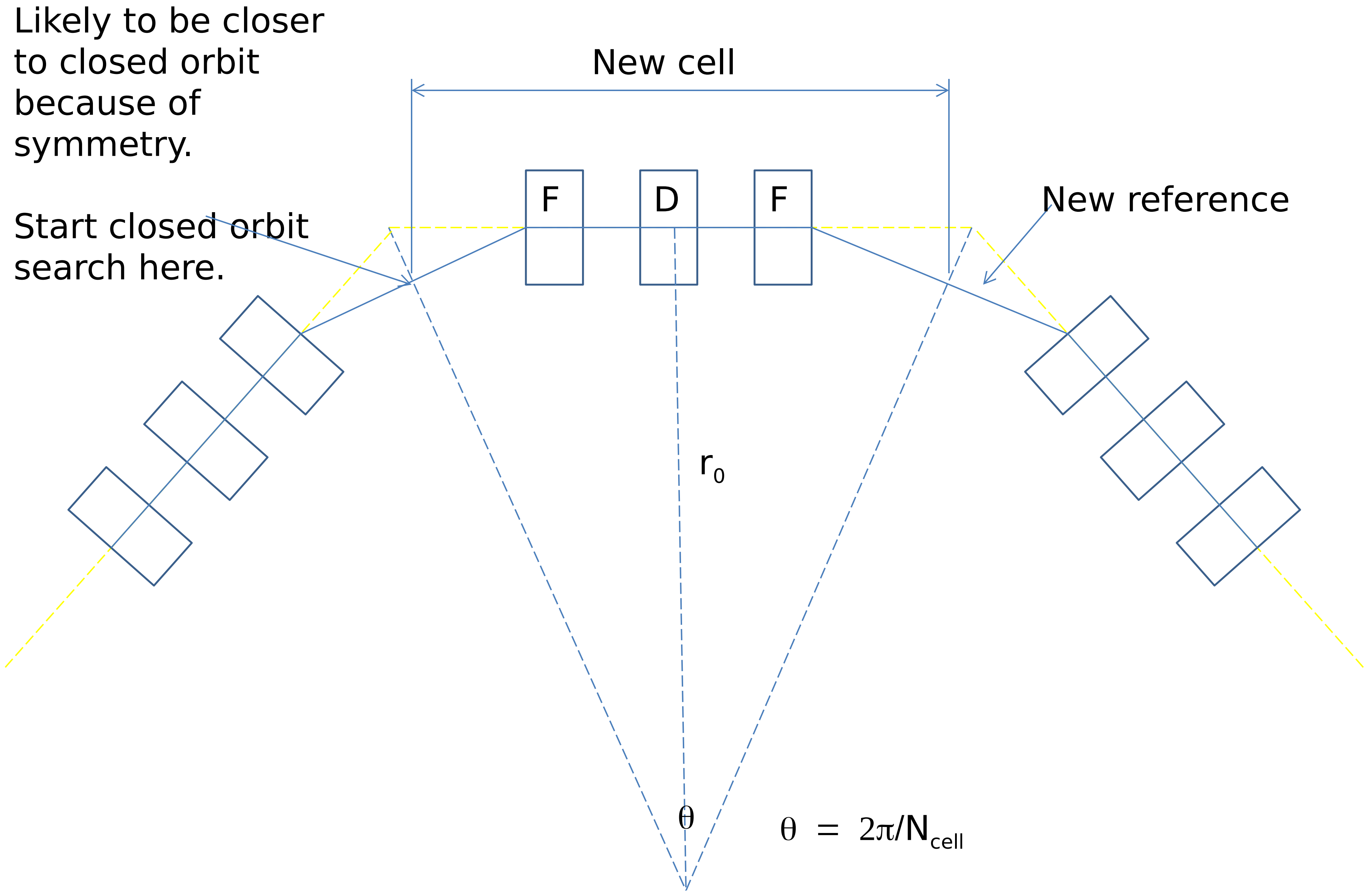
L = 0.314 m

Triplet length = 5L = αL_{ce}

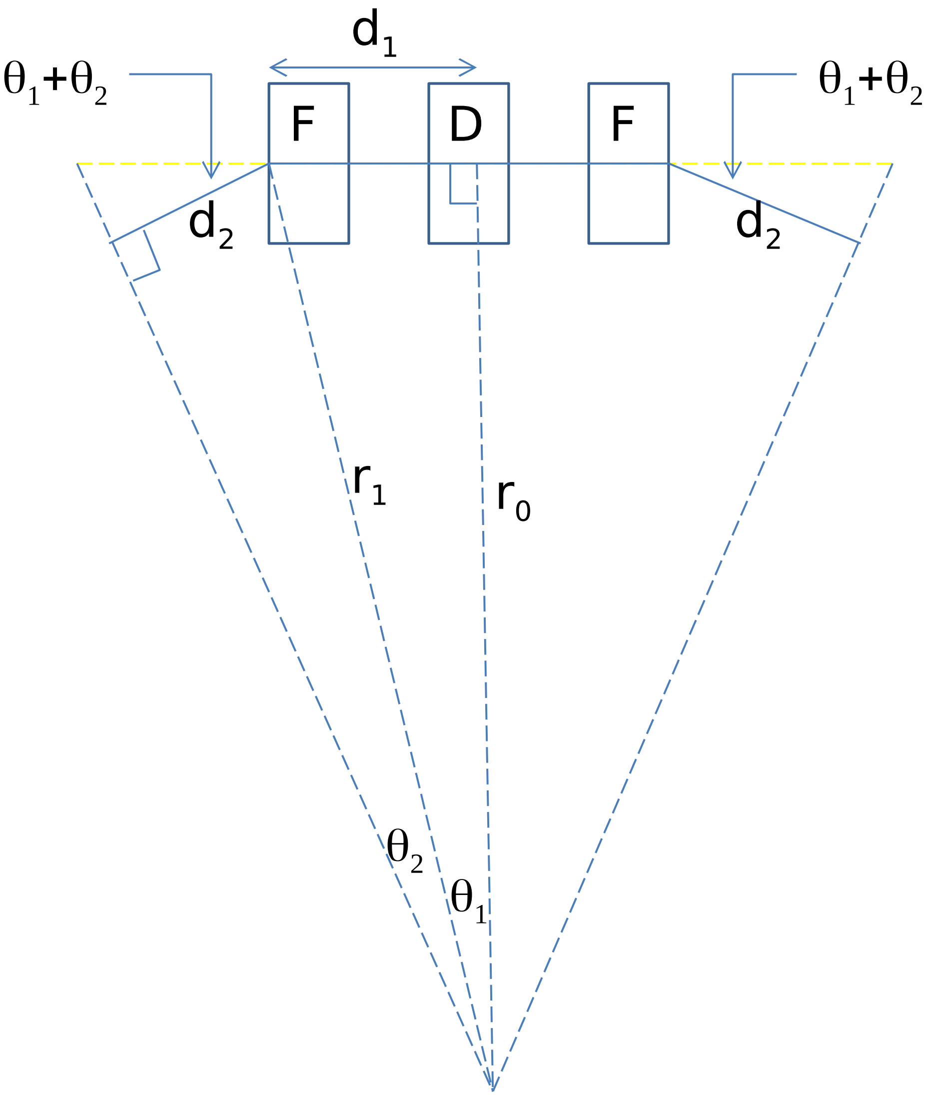


$\theta = 2\pi/N_{cell}$

Suggested reference path for Zgoubi



attice parameters needed for Zgoubi



$d_1 = 5L/2$

$\theta_1 = \tan^{-1}(d_1/r_0)$

$r_1 = r_0/\cos\theta_1$

$\theta_2 = \pi/N_{cell} - \theta_1$

$d_2 = r_1\cos\theta_2$

Magnet parameters

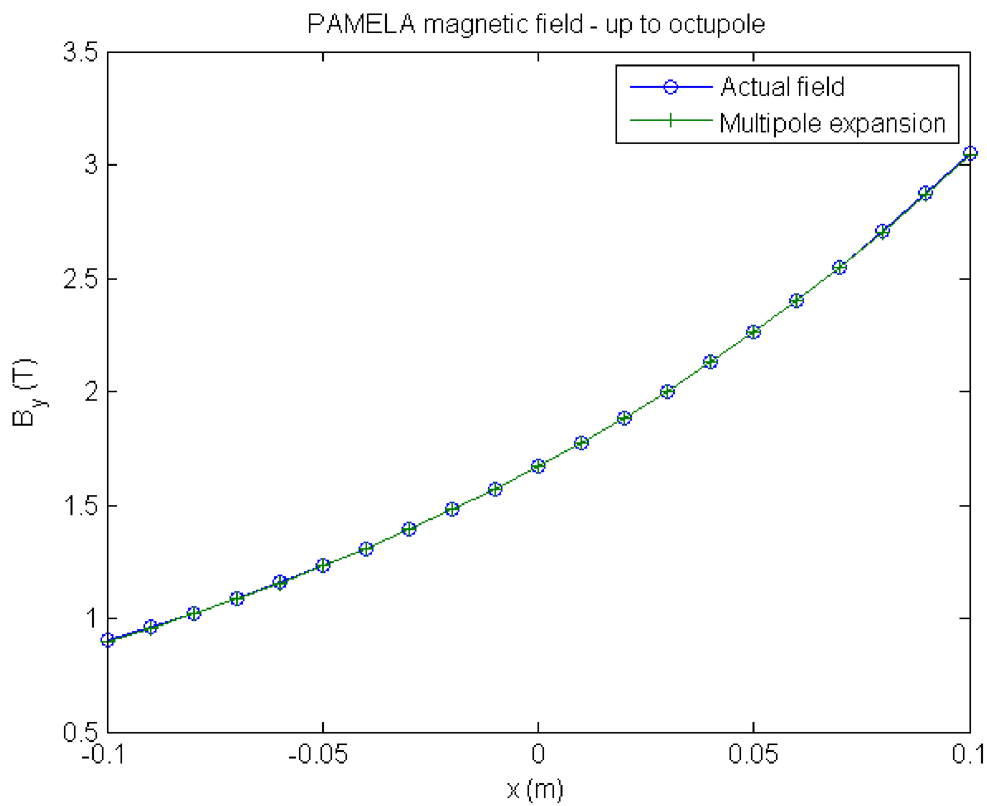
Along radial direction in each magnet, $B_y = B_0(r/r_0)^k$.

$k = 38$

$B_0 = 1.67$ T for F magnet

$B_0 = -2.44$ T for D magnet

$r = r_0 + x$



Field created by multipole expansion

Taylor expand about $r=r_0$:

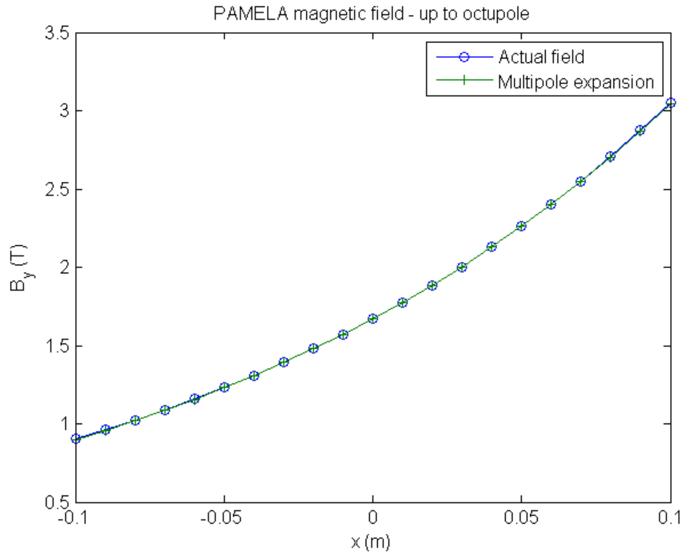
$$B_y = B_0\left(\frac{r}{r_0}\right)^k = B_0\left(\frac{r_0+x}{r_0}\right)^k = B_0\left[1 + k\frac{x}{r_0} + \frac{k(k+1)}{2!}\left(\frac{x}{r_0}\right)^2 + \frac{k(k+1)(k+2)}{3!}\left(\frac{x}{r_0}\right)^3 + \ldots\right]$$

To obtain B_x, replace each term by multipole:

$$B_y + iB_x = B_0 + B_0\sum_{n=1}^{N}\frac{k(k-1)\ldots(k-n+1)}{n!}\left(\frac{x+iy}{r_0}\right)^n$$

Check that real part agrees with previous equation for B_y. This works because each multipole term satisfies Maxwell's equations.

Since x, y << r_0, it may be possible to truncate the series. This graph compares N = 3 with the actual field.



Magnet parameters for Zgoubi

Zgoubi requires the magnetic field (magnitude) at pole tip. To find this, we first write down an expression for a multipole term. Comparing

$$B_y + iB_x = B_0 + B_0 \sum_{n=1}^{N} \frac{k(k-1)\ldots(k-n+1)}{n!} \left(\frac{x+iy}{r_0} \right)^n$$

with a sum of multipole fields B_n:

$$B_y + iB_x = B_0 + \sum_{n=1}^{N} B_n$$

the n^{th} order multipole field is given by:

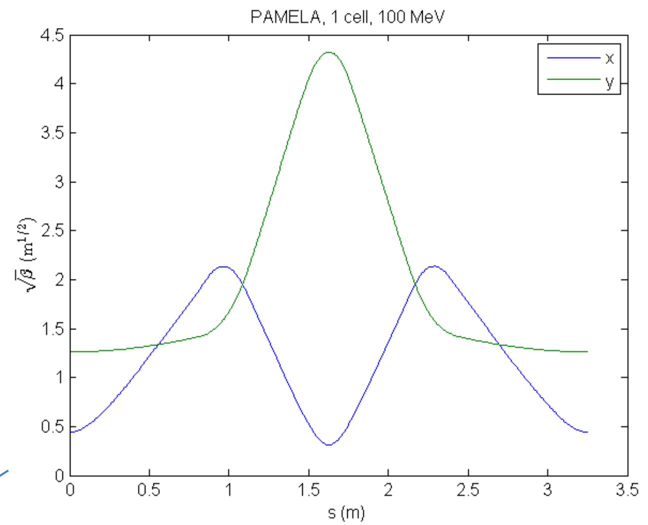
$$B_n = B_0 \frac{k(k-1)\ldots(k-n+1)}{n!} \left(\frac{x+iy}{r_0} \right)^n$$

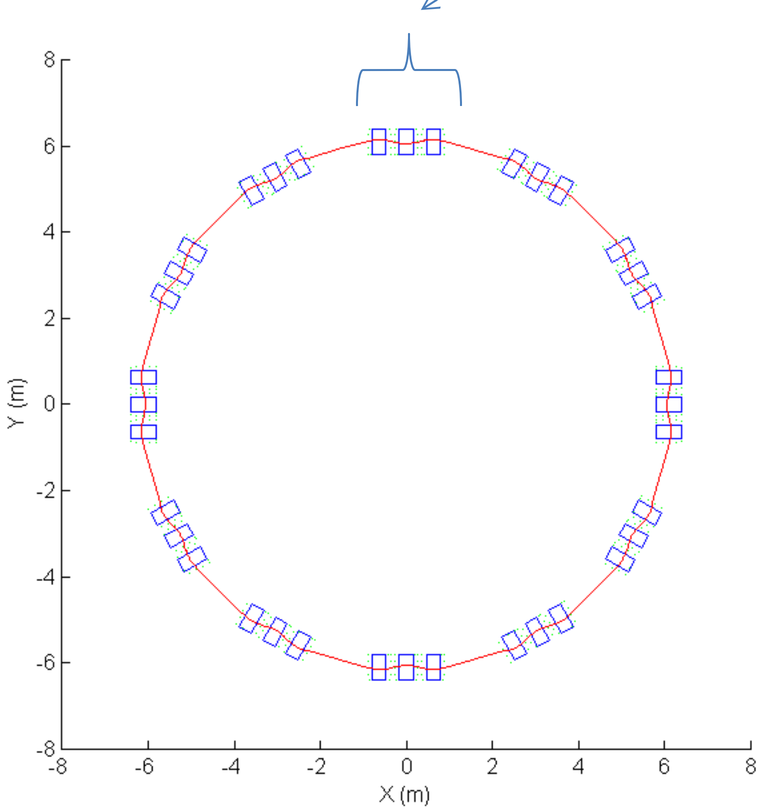
Consider a pole tip on the x axis at distance R_0 from reference path. This pole tip is at $x=R_0$, $y=0$. So at the pole tip, the field is:

$$B_n = B_0 \frac{k(k-1)\ldots(k-n+1)}{n!} \left(\frac{R_0}{r_0} \right)^n$$

For future comparison:

These results are obtained using a multipole expansion up to N=3, and for a 100 MeV proton.





References

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